APPENDIX L

SECONDARY ISSUES TO THE USE LIFE-CYCLE STAGE OF COMPUTER DISPLAYS

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1. ELECTRIC AND MAGNETIC FIELDS (EMFs)

Electric and magnetic fields (EMFs) are invisible lines of force that surround any electrical device, including power lines, electrical wiring, and electrical equipment. Electric fields are produced by voltage and increase in strength as the voltage increases. Magnetic fields result from the flow of current through wires and or electrical devices and increase in strength as the current increases. Most electrical equipment has to be turned on for a magnetic field to be produced, but electric fields are present even when equipment is switched off as long as it is connected to an electric power source. Electric fields are weakened or shielded by materials that conduct electricity (including human skin). Magnetic fields, on the other hand, pass through most materials and are therefore more difficult to shield and of greater concern. Both electric and magnetic fields decrease with distance from the source (NIOSH, et al 1996).

Most information on EMFs from video display units (VDUs) pertains to CRT monitors. The following is excerpted from the World Health Organization fact sheet, “Video Display Units (VDUs) and Human Health (1998):”

> *“The typical VDU creates images in a large evacuated cathode-ray-tube (CRT) by directing a beam of high-energy electrons from the cathode onto a special phosphor-coated glass screen. This coating emits light when struck by the fast-moving electrons. The electron beam creates the image from computer signals that control coils, at the back of the CRT, that sweep the electrons in the vertical and horizontal directions. These coils are called vertical and horizontal deflection coils. The electronic circuitry used to create the image gives rise to static electric and magnetic fields, as well as low and high frequency electromagnetic fields...*
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> *Electric and magnetic fields are emitted in three different frequency ranges. The horizontal deflection coils emit fields operating predominantly in the frequency range 15-35kHz. Extremely low frequency (ELF) fields at 50 to 60 Hz come from the power supply, transformers and the vertical deflection coils. Finally, weak signals at higher radio frequencies (RF) come from the VDU’s interior electronic circuitry and signals received from the computer.”*

Very little information was found on the relative magnitude of EMFs emitted by CRTs and LCDs. However, typical household power operates at 50-60 Hz and 120 volts – these remain relatively constant no matter how much power in watts a piece of electrical equipment needs or draws. What fluctuates with power demand is current (in amperes, or amps). CRTs consume a greater quantity of power in watts, and therefore require a larger amount of electrical current in amps. Since magnetic fields increase in strength with increased current, it is assumed a CRT will generate a larger magnetic field than an LCD. Additionally, some of the components discussed above, such as the horizontal and vertical deflection coils, are found in CRTs but not in LCDs. Thus, due to their power handling needs and capabilities, CRTs also generate EMFs that are not generated by LCDs. However, according to NoRad Corporation, a manufacturer and marketer of EMF shielding products for monitors, it is a common misconception that LCDs do not emit EMFs because of their smaller current draw; backlit LCD displays can emit significant levels of both magnetic fields and electric fields (NoRad, undated).

To address concerns about potential health effects from EMF exposure, in 1992 the U.S. Congress authorized the Electric and Magnetic Fields Research and Public Information Program (EMF-RAPID Program) and directed the National Institute of Environmental Health Sciences (NIEHS) and the Department of Energy (DOE) to direct and manage a program of research and analysis aimed at providing scientific evidence to clarify the potential for health risks from exposure to ELF-EMF (NIEHS, 1999). After several years of research, in 1999 NIEHS issued a report to Congress on the health effects from exposure to power-line frequency EMFs, which concluded the following (NIEHS, 1999):

> *"The scientific evidence suggesting that ELF-EMF exposures pose any health risk is weak. The strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupationally exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia. In contrast, the mechanistic studies and the animal toxicology literature fail to demonstrate any consistent pattern across studies although sporadic finding of biological effects (including increased cancers in animals) have been reported. No indication of increased leukemia in experimental animals has been observed.*
> *The lack of connection between the human data and the experimental data (animal and mechanistic) severely complicates the interpretation of these results. The human data are in the "right" species, are tied to "real-life" exposures and show some consistency that is difficult to ignore. This assessment is tempered by the observation that given the weak magnitude of these increased risks, some other factor or common source of error could explain these findings. However, no consistent explanation other than exposure to ELF-EMF has been identified.*
>
> *Epidemiological studies have serious limitations in their ability to demonstrate a cause and effect relationship whereas laboratory studies, by design, can clearly show that cause and effect are possible. Virtually all of the laboratory evidence in animals and humans and most of the mechanistic work done in cells fail to support a causal relationship between exposure to ELF-EMF at environmental levels and changes in biological function or disease status. The lack of consistent, positive findings in animal or mechanistic studies weakens the belief that this association is actually due to ELF-EMF, but it cannot completely discount the epidemiological findings.*
> *The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our*

opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers on non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern."

More recently, an expert scientific working group of the Monographs Programme of the International Agency for Research on Cancer (IARC) released its findings from a review of health effects of static and ELF EMFs. IARC concluded that ELF magnetic fields are possibly carcinogenic to humans, based on consistent statistical associations of high level residential magnetic fields with a doubling of risk of childhood leukemia. However, IARC also concluded that children who are exposed to residential ELF magnetic fields less than 0.4 microTesla (4 milligauss)[1] have no increased risk of leukemia (IARC, 2001). To help put this in perspective, Table L-1 presents the average magnetic field exposures for clerical workers with and without computers.[2] As shown in the table, clerical workers with computers have increased average daily exposures of about 0.07 µT (0.7 mG) over clerical workers without computers. The average daily median for workers with computers is 0.12 µT (1.2 mG) and the exposure range is 0.05 to 0.45 µT (0.5 to 4.5 mG). Only the upper end of the exposure range exceeds the exposure level that IARC concluded has an increased risk of childhood leukemia (0.4 µT).

Table L-1. Average magnetic field exposures for clerical workers*

Type of worker	Average daily median (µT)	Exposure range (µT)
Clerical workers with computers	0.12	0.05 to 0.45
Clerical workers without computers	0.05	0.02 to 0.2

Source: NIOSH Fact Sheet: EMFs in the Workplace
* The source does not give the distance at which measurements were taken. Monitor EMF emission measurements are often taken at a distance of 30 cm (approximately 12 inches) or 50 cm (approximately 20 inches).

In summary, no data were found on EMF measurements from LCDs. However, because of the lesser current requirements of LCDs compared to CRTs, it is assumed that LCDs also generate a lesser magnetic field. NIEHS has concluded that the evidence that ELF-EMF exposures pose any health risk is weak. However, since publication of the NIEHS report, IARC has classified ELF-EMFs as possibly carcinogenic to humans. Based on the data in Table L-3, it

[1] Magnetic field intensity is measured in units of tesla (T) or gauss (G). One tesla equals 10,000 gauss. Since most environmental EMF exposure involve magnetic field intensities that are only a fraction of a tesla or a gauss, they are commonly measured in units of microteslas (µT) or milligauss (mG). One µT is equal to 10 mG.

[2] Given the fact that desktop LCD monitors were only recently introduced into the marketplace, it is assumed that the computers used by clerical workers for whom measurements were taken were equipped with CRT monitors, although the data could also include clerical workers who used laptops with LCD displays.

appears most exposures to ELFs-EMFs from computer displays may be below the carcinogenicity concern level determined by IARC (0.4 μT).

2. ERGONOMIC ISSUES

Merriam-Webster's Online Dictionary defines ergonomics as "an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely – also called human engineering." While CRT and LCD desktop monitors are both usable in the same environments (in most cases), there are differences in their sizes and the way they present information to the user in their working environment. Thus the potential exists for there to be differences in the way a user might physically interact with their CRT or LCD monitor. (Note that Eye Strain is addressed as a separate issue in this Appendix [see L.3], and issues related to image generation on the monitor surface are addressed there.)

In reviewing several documents on ergonomics and the placement of computer monitors in or around a user's working area, some sources discuss the differences in using a CRT versus an LCD monitor. It is assumed in most discussions that the user is able to move/adjust the monitor to within a recommended operating position for use (e.g., eye-to-screen distance, vertical monitor location [with respect to horizontal eye level]). Thus, with unlimited resources within which to setup a computing environment, it is expected that only viewing angle would potentially favor a CRT over an LCD. CRTs provide a horizontal viewing angle of 180˚ whereas early-model LCD monitors were limited to an almost straight on view. The most recent LCDs on the market have a 120˚ capability (EIZO 1999). Although less than the CRT horizontal viewing angle, these current viewing angles significantly diminish the differences in viewing ability between the two monitor types. The reduced viewing angle of the LCD appears to mainly be a factor when presenting information to users who are viewing the screen from the side, such as during presentations to multiple users.

However, the user's environment is often limited by physical constraints on where the monitor can be placed and user seated. With this in mind, the physical size and footprint of the monitor becomes more of an ergonomics issue. In cases where the footprint of a monitor dictates that the monitor not go directly in-front of the user, but to either the left or right side, an increased level of ergonomic stress may be realized (typically neck twist) if the user is unable to adjust his or her seated position accordingly. Even the smaller footprint CRTs being manufactured today have a much larger footprint than those of closely-equivalent LCD monitors, typically occupying almost six times the depth of LCDs (IBM 1999). Additionally, some LCD monitors can be wall-mounted, almost completely removing the monitor from the desktop. Thus, it appears that the smaller footprint of the LCD may offer benefits in more easily positioning the monitor for optimum user use.

3. EYE STRAIN

There are numerous sensations that can be interpreted to be eye strain in the use of monitors, including but not limited to burning, tightness, sharp pains, dull pains, watering, blurring, double vision and headaches. Many of the principal factors that cause eye strain can be corrected or improved by adequately setting up the computing environment (e.g., controlling the distance between the eyes and the screen, wearing corrective lenses, if needed, etc.). Others can be improved by adjusting the controls on the monitor (e.g., setting brightness or contrast). Of the factors identified in this study, glare and screen flicker are the two that appear to be most affected by the technology choice (e.g., CRT or LCD).

The distance between your eyes and the monitor should be at least 25" (Ankrum 1996), and using a CRT versus an LCD should have no effect on the necessary distance needed to clearly see the monitor screen, as long as the user is using an appropriately sized resolution for his or her monitor size. Both CRTs and LCDs should be equally readable, not considering the viewing of an LCD from outside its particular viewing angle. If the brightness levels of a CRT and LCD are set appropriately, then the contrast between what is being looked at and its immediate environment should be no different for the two monitor types. Lastly, a user has to have good or corrected vision before either monitor will be useful.

The only notable difference between CRTs and LCDs with respect to glare is their flatness. As LCDs have completely flat monitor surfaces or screens, versus most CRTs which have rounded screens, they significantly reduce the probability of reflected glare from overhead or nearby lights. There are two main types of CRT tube technology, shadow mask and aperture grill. Shadow masks are utilized in older, less flat monitors, and aperture grills are utilized in the more current variations that have flatter outside faces (IBM 1999). Flatter screens provide less opportunity for the occurrence of reflected glare.

CRTs, especially older models, may be prone to screen flicker, which contributes significantly to eye strain. CRT's use phosphor that has been excited by an electron beam to create light. After the phosphor is excited, it begins to decay. The electron beam needs to return to the phosphor in a specific amount of time to keep the phosphor from decaying to the point that the human eye can perceive it. The rate at which the electron beam returns to any given phosphor is called the refresh rate. If the refresh rate is too low, the decaying of the phosphor may be perceptible to the human eye as a flickering screen image. Because LCDs do not use phosphors to create the image they do not have a refresh rate and do not flicker.

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